

Research Brief for DOE/IHEA Process Heating Materials Forum

Research Title: Materials Low-Cost Sensor Array System for High-Temperature Gas Measurement

Industry Need: The industry has identified key barriers as having limited direct process measurement sensors and the inability to reliably monitor and control critical product parameters. The lack of measurements also leads to the inability to reliably control processes and provide reproducible product quality. Materials for high temperature sensor operation are a key to providing robust, accurate sensors.

Existing Research: There is R&D underway at several national laboratories and companies to produce robust, high temperature sensors. ORNL has worked with various industry partners through CRADAs to develop some individual high-temperature ceramic sensors and oxygen sensors that function to 1100°C and a NO_x sensor demonstrated at 400°C. These sensors can be manufactured at very low cost in volume production. Initial work has started in sensing ammonia, hydrogen, and carbon monoxide.

Previous developments have included porous materials for control of gas diffusion, sintering technology for reduce processing temperature of alumina, high conductivity thin films, and novel materials for catalysts and electrodes.

The next step in this area is to integrate the single sensors into a multi-measurement array with signal conditioning electronics to achieve a low-cost, robust system that can measure multiple parameters; emissions, process chemistry, etc. ORNL has a unique analog-design group that specializes in low power, low-cost CMOS electronics and has developed numerous components for operation to 200°C and higher.

Proposed Activity: We propose to combine several of these high-quality sensors on a tightly integrated ceramic probe with associated readout chip. Beginning with oxygen and NO_x sensors, we would continue the development of carbon monoxide, ammonia, SO_x, and H₂S sensing that would be integrated in the multi-sensor array. Material issues and packaging will be significant efforts. The sensors are based on a resistive mixed potential technique and are fabricated using multiple layers. The fabrication facilities already exist at ORNL that can produce up to 1000 multilayer ceramic sensors a year. Material issues to be address include integration of interdigitated electrode with alumina body, electrodes, reduction catalyst development, interference from other gases, and material aging issues. Material development is a significant challenge and the response to this challenge can be by aided by material modeling and lifetime predictions. The challenge to design a robust thermochemical sensor will be met when the coupled thermal-chemical-mechanical stress state of the service conditions(s) and the potential thermomechanical performance of the metal oxide ceramics are both understood. The key will be to engineer sensor designs whose developed thermomechanical strains never

exceed the strength (for deterministic design) or that never exceed an acceptable probability of failure (for probabilistic design, which is the method preferred for this project). Development will be undertaken experimentally and, with probabilistic models, to predict the stress state and the ceramic oxide performance. The results will be used to modify materials and sensor geometries to create robust sensor performance in harsh environments.

The materials will be directly applicable multi-sensor arrays that can operate in harsh environments to meet industry needs for in-process real-time measurement and control of chemistry and emissions.

Lead Scientist:

Tim R. Armstrong,
Oak Ridge National Laboratory
P. O. Box 2008, MS 6084
Oak Ridge, TN 37831-6084
Phone: (865) 574-7996
Fax: (865) 5741-4357
Email: armstrongt@ornl.gov

James E. Hardy
Leader, Sensor and Instrument Research Group
Oak Ridge National Laboratory
P. O. Box 2008, MS 6004
Oak Ridge, TN 37831-6004
Phone: 865-576-8670
Fax: 865-574-1249
Email: hardyje@ornl.gov